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POSSIBLE DISPLACEMENT OF THE NEUTRAL SHEET DUE TO ASYMMETRY OF ACTIVITY ON THE SUN

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Abstract

Annual totals of the number of sunspots occurring on the northern and southern hemispheres of the sun between 1965 and 1983 are shown to be correlated with asymmetries in the number of days during which the interplanetary magnetic field measured at the earth is towards or away from the sun. It is hypothesized that this is the result of the displacement of the source of the neutral sheet away from the solar hemisphere in which more sunspots occur.

Introduction. Magnetic conditions within the heliosphere derive their basic topology from the magnetic state of the sun. Thus for the bulk of each solar cycle the heliosphere is divided into two regions of opposite magnetic polarity, the boundary between which is called the neutral sheet. This has a warped shape, reminiscent of a ballerina's skirt, with the amplitude of the warp being roughly correlated with sunspot number.

As the neutral sheet co-rotates with the sun, any object in solar orbit, such as the earth, encounters alternate regions of positive and negative magnetic polarity as the sheet overtakes it. When first observed these regions were called magnetic sectors (Svalgaard, 1976).

If the source of the neutral sheet is centered, on average, about the heliospheric equator one would expect that over a period of a year the neutral sheet would be above (i.e. north of) the earth as often as it would below it. Consequently the number of days of positive and negative magnetic field (away from and towards the sun respectively) should be approximately equal. Any asymmetry in the number of days observed for each polarity might be expected to be connected with some form of solar asymmetry.

North-South Asymmetry. Hisako Koyama observed the sun carefully and rigorously, on a daily basis using the same telescope and method of observation, between 1947 and 1984 (Koyama, 1985). Her data set includes sunspot number (total, northern hemisphere and southern hemisphere) for as many days as possible through this period. We have correlated her

hemispheric sunspot numbers with available spacecraft and other observations of the interplanetary magnetic field (IMF) polarity near the earth. Some of the data on north-south asymmetry in solar activity have also been described by Swinson, Koyama and Saito (1986).

Figure 1 displays Koyama's data for northern hemisphere (dots) and southern hemisphere (solid line) sunspot numbers from 1965 to 1983; the plot is shaded when northerly sunspots predominate. It can be seen that prior to the solar magnetic polarity reversal in 1969-1971 more sunspots occurred on the sun's northern hemisphere than on its southern hemisphere. After the magnetic polarity reversal, sunspots on the sun's southern hemisphere dominated in number until the solar minimum in 1975. This pattern, of northern domination until polarity reversal at solar maximum followed by southern dominance, was continued in the following solar cycle until the end of our data set in 1983.

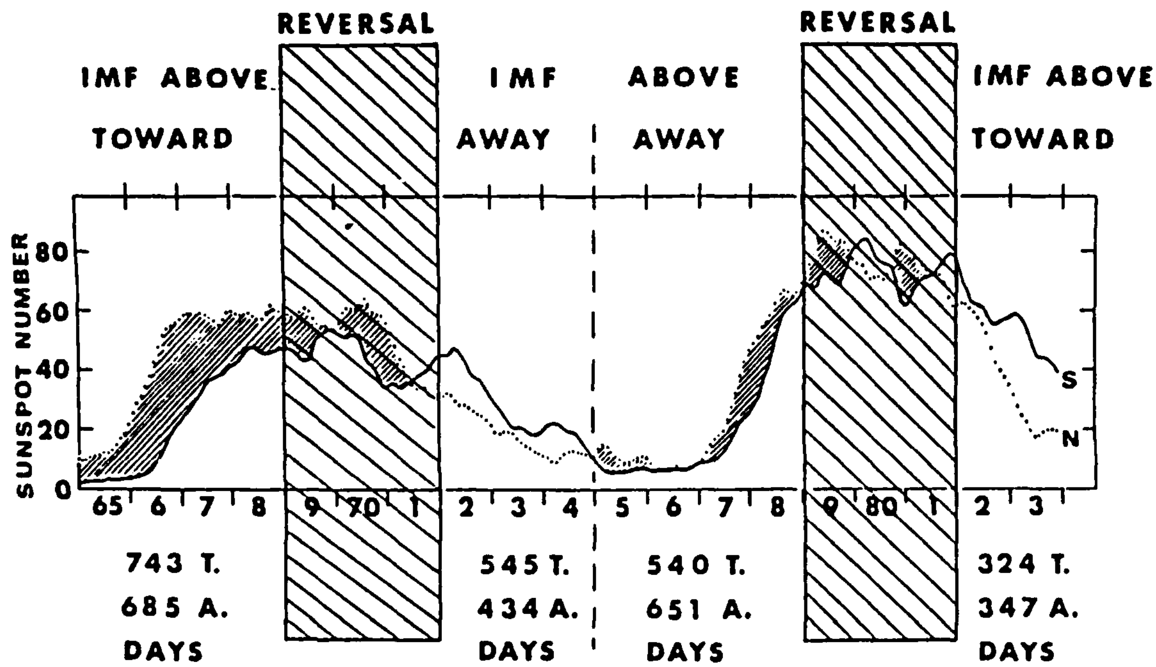

Figure 1. Northern (N) and Southern (S) sunspot numbers, 1965-1983.

For the purposes of this analysis we omit the times of solar polarity reversal, as indicated by the barred areas in Figure 1. During these periods the morphology of the neutral sheet is quite complex and no consistent and regular pattern is observed (Hoeksema et al, 1983). Between these reversals of 1969-71 and 1979-81, however, the neutral sheet has a relatively "well-behaved" and consistent shape and is therefore amenable to the type of analysis we are performing here.

The IMF polarity above the neutral sheet is presented at the top of Figure 1. Before the 1969-1971 reversal, and after the 1979-1981 reversal, the field above the neutral sheet was toward the sun (or negative) whilst during the period between the two reversals it was directed away from the sun. At the bottom of Figure 1 are listed the number of days when the IMF was directed toward (T) the sun or away (A) from the sun for each of the four different epochs 1965-68, 1972-74, 1975-78 and 1982-83.

The IMF polarity in the vicinity of the earth for a given day was determined from data from a number of sources. For most of the days direct measurements from various spacecraft were available, as were inferences of its direction obtained from polar magnetograms (e.g. Svalgaard, 1976; Solar-Geophysical Data Prompt Reports). It was also estimated by noting the Stanford Mean Solar Magnetic Field (Solar-Geophysical Data Prompt Reports) for individual days and by moving them in time by five days to infer the IMF direction at the earth five days later. Use of all of these techniques resulted in measurements or estimates of the IMF direction at the earth being available for most of the days between 1965 and 1983. The discrepancy between the total number of T and A days in any given period and the number of actual calendar days in that period mostly results from the rejection of those days for which the observations or the inferences leave doubt as to the average IMF direction for the day concerned.

Model Prediction. Figure 2 presents a schematic representation of the long-term average position of the neutral sheet relative to the ecliptic plane, for each of the four epochs being considered, based upon the hypothesis that excess activity (as represented by sunspot number) in one solar hemisphere will displace the source of the neutral sheet away from that hemisphere. There will still be many days during which the neutral sheet will be above the ecliptic plane, and many days during which it will be below the plane, but there should be in these circumstances more of one set than of the other. In 1965-68 there were more sunspots in the northern

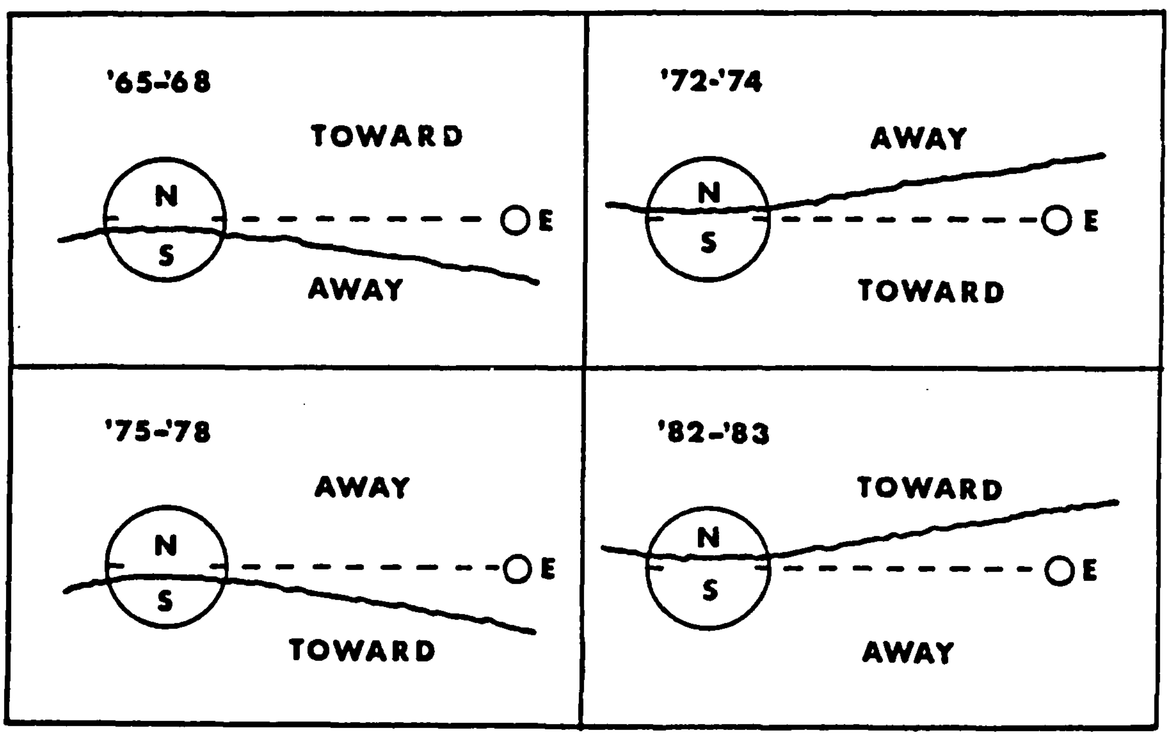

Figure 2. Schematic representation of the displacement of the source of the neutral sheet on the sun due to a greater proportion of sunspots in either the northern or the southern solar hemispheres. The figure shows the resulting average location of the neutral sheet in each of the four epochs, and also the relevant IMF polarities.

solar hemisphere than in the southern, and so our hypothesis leads to the source of the neutral sheet being displaced towards the south. The neutral sheet should therefore be more often below the earth than above it, and there should be more days of toward (T) IMF polarity at earth than days of A polarity. This is indeed what is observed, as noted in Figure 1.

Similarly, in each of the other three epochs the excess of T or A days predicted by our hypothesis (Figure 2) from the observed hemispheric sunspot distribution is actually observed (Figure 1). Further support for this hypothesis comes from observations of cosmic ray density gradients at high rigidities (Swinson, Shea and Humble, 1986; Swinson et al., 1990, this conference in SH 6.2-3).

Conclusions. We conclude that asymmetries in solar activity between the northern and southern hemispheres of the sun can influence the position on the sun of the source of the neutral sheet. In particular, we suggest that the source of the neutral sheet is displaced away from the solar hemisphere having the higher level of solar activity as expressed by the sunspot number. This in turn leads to the earth spending more time, on average, either above or below the neutral sheet, resulting in an asymmetry in the frequency of toward or away polarity of the IMF near the earth. Data for all four possible combinations of north-south asymmetry in sunspot number and heliospheric magnetic polarity support this model.

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